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UCAR Visiting Scientist Program at the National Ice Center

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LONG TERM GOALS

The long-term goal of the University Corporation for Atmospheric Research (UCAR) Visiting Scientist Program (VSP) at the National Ice Center (NIC) is to recruit the highest-quality visiting scientists in the ice research community for the broad purpose of strengthening the relationship between the operational and research communities in the atmospheric and oceanic sciences.

The University Corporation for Atmospheric Research supports the scientific community by creating, conducting, and coordinating projects that strengthen education and research in the atmospheric, oceanic and earth sciences. UCAR accomplishes this mission by building partnerships that are national or global in scope. UCAR's goal is to enable researchers and educators to take on issues and activities that require the combined and collaborative capabilities of a broadly engaged scientific community.

OBJECTIVES

The objectives of the UCAR Visiting Scientist Program at the NIC are:

- Manage a visiting scientist program for the NIC Science Center in support of the mission of the NIC.
- Provide a pool of researchers who will share expertise with the NIC and the science community.
- Facilitate communications between the research and operational communities for the purpose of identifying work ready for validation and transition to an operational environment.
- Act as a focus for interagency cooperation.

The NIC mission is to provide worldwide operational sea ice analyses and forecasts for the armed forces of the U.S. and allied nations, the Departments of Commerce and Transportation, and other U. S. Government and international agencies, and the civil sector. The NIC produces these analyses and forecasts of Arctic, Antarctic, Great Lakes and Chesapeake Bay ice conditions to support customers with global, regional and tactical scale interests. The NIC regularly deploys Naval Ice Center NAVICECEN Ice Reconnaissance personnel to the Arctic and Antarctica in order to perform aerial ice observation and analysis in support of NIC customers. NIC ice data are a key part of the U.S. contribution to international global climate and ocean observing systems.

APPROACH

The UCAR Visiting Scientist Program at the NIC works with participating Federal agencies to recruit scientific visitors and recent PhDs who are interested in conducting applications-oriented research and product evaluation of relevance to the NIC ice-monitoring mission. The UCAR visiting scientists are a source of expertise for the NIC as well as mentors to the recent PhDs.

Participating agency representatives have been:

- Waleed Abdalati: NASA program sponsor
- Tony Beesley: UCAR Visiting Scientist
- Cheryl Bertoia: National Ice Center liaison to UCAR
- Dennis Conlon: Office of Naval Research, program sponsor
- CDR Michael D. Foster, PhD: Executive Officer, Naval Ice Center (visitor program sponsor/advisor)
- Phil Hovey: NOAA physical science technician
- Eric Lindstrom: NASA program sponsor
- John Marra: NASA program sponsor
- Ted Maksym: UCAR Visiting Scientist
- Walt Meier: UCAR Visiting Scientist
- CDR Gary M. Mineart: Director, National Ice Center & Commanding Officer, Naval Ice Center (visitor program advisor)
- Kim Partington: NIC Chief Scientist, then served as a NASA Polar Programs Manager (NASA advisor to program)
- John Powell: Executive Officer, Naval Ice Center (visitor program sponsor & advisor)
- Juanita Sandge: NRL Stennis Space Center program sponsor
- Eric Sogard: NRL Stennis Space Center program sponsor
- CDR Zdenka Willis: Director, National Ice Center & Commanding Officer, Naval Ice Center (visitor program advisor)
- Michael VanWoert: NESDIS program sponsor & now NOAA Senior Scientist serving as NIC's Chief Scientist
- Cheng-Zhi Zou: UCAR Visitor Agreement

WORK COMPLETED

This ONR sponsored activity covered two areas: SSM/I ice concentration algorithms, and the Polar Ice Prediction System (PIPS). The remainder of this report covers these two areas.

SSM/I WORK COMPLETED

1. Completed evaluation of SSM/I ice concentration algorithms. Significance of this is that NIC operations depends on SSM/I when other data sources are unavailable, including vast areas of the Southern Ocean. There are significant differences between different algorithms and a knowledge of their relative merits and deficiencies can assist analysts greatly in attempting to counteract these biases in their analyses.

2. Completed development of new data fusion SSM/I ice concentration algorithm. The aim of this algorithm is to make use of SAR, AVHRR and OLS data in "optimizing" the SSM/I algorithm. This is a novel and automated algorithm that will, effectively, tune the SSM/I algorithm to the time and region of interest.

3. Supported evaluation and modification of Advanced Knowledge Based System for Sea Ice Classification (ARKTOS). This algorithm is a highly advanced, rule-based, artificial intelligence system for SAR data developed by the University of Kansas. My role was to help in optimizing the rules of the system to help its performance.

4. NOW campaign. The NIC science team was involved in the North Water campaign in collaboration with the Canadian Ice Service and others. This involved the collection of a comprehensive test data set including a wide range of remote sensing data, both satellite-, helicopter- and ship-borne, plus surface measurements. The test data set has been organized so that it will provide a resource for future algorithm testing and research, in line with our stated mission of assisting the scientific community with resources for evaluating their techniques. In addition, specific projects are underway including the analysis of data from the ship-borne radiometer system, which has been tied in with digital video data and ground survey sites to test new SSMI algorithms and the sensitivity of the sensor to new ice. A theoretical model of passive microwave signatures has been implemented as part of the NIC contribution to this project, which treats the sea ice as an ice layer overlain by snow.

5. Collaboration with the Danish Meteorological Institute is underway. This has already resulted in the working visit of a scientist - Soren Andersen - from that institute. Sources of funding have been identified for a return visit by one of the new science program post-doctoral fellows, early in 1999. The area of joint research is related to SSMI and the improvement of atmospheric corrections. The precise direction of the research is to be refined further pending completion of the appointment of the post-doctoral fellow at NIC. This activity feeds directly into our objective of evaluating US and foreign algorithms and products, with the Danish Met. Institute probably being the most active European center for development of operational ice products.

6. Scientific support to the National Ice Center. The science program has involved providing scientific support to the Director of Operations, in monitoring of contracts related to development of SAR algorithms and future planning issues. This activity is valuable in ensuring that the senior scientist is aware of evolving operational requirements.

7. We have taken on a student assistant to manage and support the data and software facilities of the science program. This student is funded separately through NIC.

SSM/I SCIENTIFIC/TECHNICAL RESULTS

1. The evaluation of SSM/I ice concentration algorithms involved the NASA Team algorithm and the Bootstrap algorithm (the two most popular algorithms in the science community) and the CAL/VAL algorithm (the algorithm used in the operational community). Substantive conclusions were:

- differences in ice concentrations predicted by the algorithms vary by up to 50% ice concentration in the Sea of Okhotsk in winter.

- the NASA Team algorithm treats thin ice as open water. The CAL/VAL algorithm treats thin ice as low concentration sea ice. The Bootstrap algorithm has intermediate behavior. None of these deal effectively with thin ice. The NASA Team algorithm modified for thin ice is effective only when no old ice is present, for example in the Sea of Okhotsk.
- the NASA Team algorithm has a very conservative ice edge as it is based on the low resolution 19 GHZ channel. The NASA Team ice edge is generally some 20 km further equatorward than the CAL/VAL and Bootstrap ice edges. The Bootstrap and CAL/VAL algorithms, which use the 37GHz channel at the ice edge, resolve the ice edge better than the NASA Team algorithm.
- the CAL/VAL algorithm saturates away from the ice edge and therefore is not effective at locating open water in pack ice.
- all algorithms under-estimate ice concentration in summer, but to varying degrees. CAL/VAL algorithm under-estimates concentration the least and the NASA Team algorithm the most.
- use of laboratory studies of passive microwave signatures, combined with algorithms, suggest that the algorithms in general have a "noisy" response to ice during the growth stage up to about 30 cm and have some sensitivity to snow thickness and ice type.
- use of passive microwave algorithms for old ice concentration are insufficiently reliable for operational use.

2. Development of new data fusion algorithm for ice concentration from SSMI. This algorithm appears to be (a) stable (b) successful in creating convergence between the SSM/I algorithm and ice concentrations derived from cloud-free visible data and SAR data.

3. Tuning of ARKTOS. The performance of this system improved markedly after iteration with the rule base to which I contributed. The performance in summer remains shaky, but winter performance is now at the point where the system could be migrated to the operations floor at NIC.

4. A suite of image analysis algorithms has been developed and installed under AVS - a visual programming and data visualization display tool. Some 60 programs have been written, broadly divided into (a) data ingestion programs, (b) statistical programs (eigenvector analysis, least squares, etc.), (c) theoretical modeling (passive microwave) and (d) data visualization.

5. Initial results of the SSMI Interpolation Scheme described above are encouraging. For summer data, the scheme has a bias of +2.8 in ice concentrations compared to a signle ice chart, compared to -8.0% for the NASA Team algorithm. However, this is a very early result - the evaluation needs to be extended significantly before any firm conclusions can be drawn.

6. As background work to the SSMI interpolation scheme, some analysis of the principal components of the SSMI data have been carried out which suggest that whilst the two principal components of the 7 channel SSMI data relate to total and old ice concentration, a third principal component has variance above the noise level and probably is related to snow conditions (albeit with weather artifacts included - this component is strongly related to the 85 H Ghz and 37V channels). Theoretical modeling is being used to attempt to clarify the most significant influences on the SSMI channels in ice after the presence of open water and fresh (old) ice. If this third component is related to some other geophysical characteristic of the ice, then this could be very useful, even with weather sensitivity.

7. Although the science program has provided only a supporting role, two SAR image classification systems that NIC has sponsored have been delivered to NIC and are undergoing evaluation. These include systems from the Univ. Kansas and the Univ. Colorado for classifying sea-ice using RADARSAT data. The science program has been involved providing advise into the evaluation and tuning of these systems.

SSM/I IMPACT FOR SCIENCE (and/or) SYSTEMS APPLICATIONS

UCAR's Visiting Scientist Programs have served many federal agencies in developing valuable partnerships between the research and operational communities. The benefits have included an influx of new ideas and collaborations, and the improvement of products for the agency, the scientific community and for society at large.

1. SSM/I algorithms. As a result of my analysis, recommendations were sent to Fleet Numerical Modeling and Oceanography Center (FNMOC) for alteration of the operational SSMI produce provided to NIC.

2. New data fusion algorithm for SSMI. This algorithm is currently being implemented on the Operations Floor at NIC for operational testing and use.

3. ARKTOS. This system is currently being evaluated further by two NIC ice analysts prior to full operational use.

A paper was submitted to IEEE Transactions on Geoscience and Remote Sensing called "A new data fusion algorithm for derivation of sea ice concentration from SSMI data", currently under review. A poster and two oral papers were presented at IGARSS 99 in Hamburg, July 1999.

SSM/I TRANSITIONS

SSM/I ice motion vectors are an important source of data for constraining sea ice models (Meier et al., 2000). Code was recently transitioned to FNOC to operationally produce sea ice motion vectors.

SSM/I RELATED PROJECTS

The GCM study of cloud feedbacks in Arctic climate collaborative work with Dr. Michael Schlesinger from the University of Illinois, and funded by the International Arctic Research Center in Fairbanks, Alaska.

PIPS WORK COMPLETED

This ONR sponsored activity is developing an improved Polar Ice Prediction System (PIPS) and to verify its use for short-term operational sea ice forecasting. The NIC science team is responsible for four PIPS related activities: 1) to evaluate the quality of the SSM/I sea ice product used to initialize the PIPS system; 2) to evaluate the suitability of the Naval Operational Global Atmosphere Prediction System (NOGAPS) for forcing the PIPS system; 3) to evaluate the skill of the PIPS forecasts; and, 4) to assemble a PIPS case study database of satellite data for validating the model dynamics.

Figure 1 provides a schematic diagram depicting the various elements of the NIC PIPS verification and validation activities.

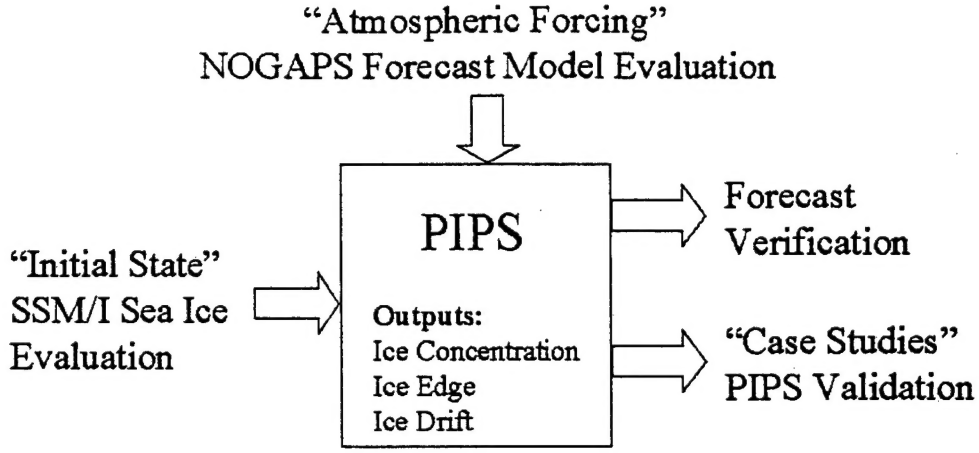

Figure 1. This schematic depicts the NIC PIPS validation and verification activities. The different approaches used for each activity are:

1. To evaluate the SSM/I sea ice algorithms, algorithm outputs are intercompared and then compared against National Ice Center charts and RADARSAT satellite imagery. As appropriate, other ancillary data are used to verify the environmental conditions at the time of the satellite product. (W. Meier)

2. The NOGAPS atmospheric model is evaluated against in situ data collected during the Surface HEat Budget of the Arctic (SHEBA) experiment. Direct comparisons between model and in situ atmospheric pressure, air temperature, and wind provide quantitative assessments of the quality of the NOGAPS fields. (T. Beesley)

3. The PIPS sea ice concentration and edge forecasts are being evaluated using statistical methods designed for model validation. Currently the focus is on establishing the root mean square error (RMSE) between the model forecast and observed conditions (Willmott et al., 1985). However, other forms of skill assessment are also being considered (e.g. Stephenson, 2000) (M. Van Woert/P. Hovey)

4. The test case database is a collection of five sets of satellite imagery depicting various sea ice conditions. The satellite imagery are being converted to GIF format and provided to the PIPS development team. (M. Van Woert/P. Hovey)

The work completed on this activity is:

1. To date activities have focused on comparing the Navy operational Cal/Val SSM/I sea ice concentration algorithm to the NASA Team algorithm and the NASA Team algorithm modified to handle thin ice regions (ThinTEAM). Focus has been on evaluating specific case studies, but attention is now turning to more comprehensive comparisons.

2. We have made an initial assessment of the NOGAPS pressure, temperature, and wind fields by comparing the model fields to data collected during the SHEBA program.

3. In preparation of model verification, we have begun assembling a database of PIPS nowcast, forecast, and SSM/I satellite-derived sea ice fields. The database begins January 1, 2000 and is ongoing. A milestone in the database development is the collection of data during the ice melt season (completed) and the freeze-up (currently being collected) period. Evaluation of the data is now underway. An example of a forecast field, the observed conditions at the valid time for the forecast, and their difference is shown in Figure 2.

4. Initial entries into the sea ice case study database have been made. The first and second case studies are from 13-17 July and July 17-26 1998 in the Beaufort Sea. They focus on large multi-year and first-year ice floes at a time when the ice edge is well north of its climatological limit. Case study three (31 January – February 4 2000) captures the rapid growth of ice near the Pribilof Islands in the Bering Sea. Case study four (7-10 January 2000) captures an extreme regression of the ice edge in the Barents sea, which is the result of strong and sustained winds from the south. Case study five from 17-19 June 2000 shows a recurring polynya in the Barent Sea. Other case studies are being evaluated for inclusion in this database.

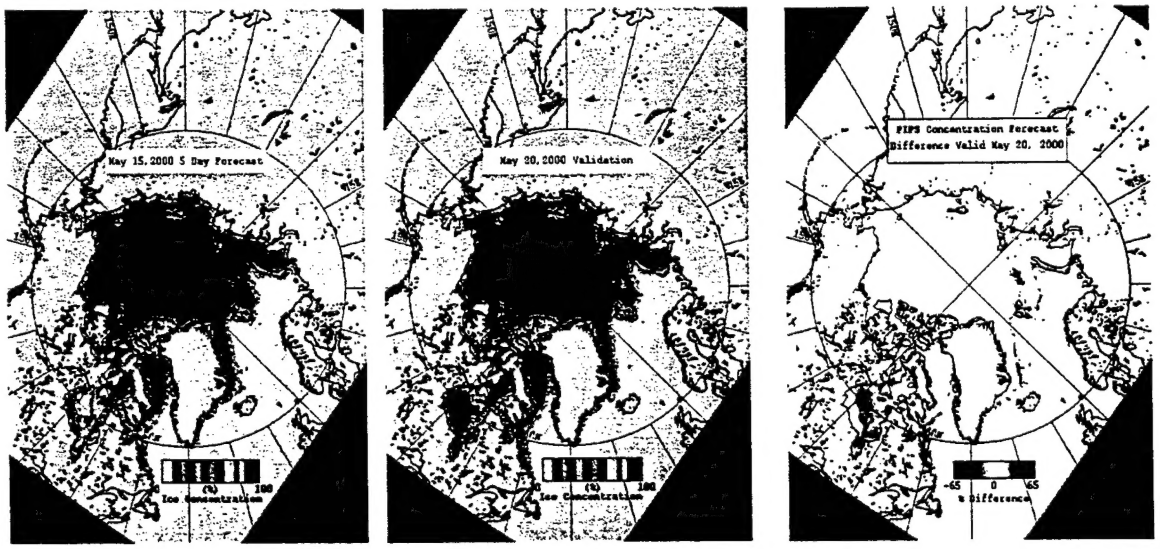

Figure 2. Five day forecast made on May 15, 2000 which is valid for May 20, 2000 (a), valid conditions on May 20, 2000 (b) and the difference (observed minus the forecast) (c). Red denotes areas where ice was observed and no ice was forecast; blue denotes areas where ice was not observed yet was forecast.

PIPS RESULTS

1. SSM/I-derived ice concentration imagery using the Navy Cal/Val, the NASATEAM and the ThinTEAM algorithms were compared for the period November 1999 – January 2000. The results of our study indicate that the ThinTEAM performs comparable to the Cal/Val in regions of operational interest, particularly near the ice edge and in thin ice regimes. Additionally, ice concentrations from the ThinTEAM algorithm retain spatial variability in central pack where the Cal./Val traditionally tends to saturate. Thus, the ThinTEAM seems to be a viable alternative to the Cal/Val algorithm in the regions of highest operational interest while retaining structure in high Arctic areas as well. Figure 3 illustrates the difference between the Cal/Val and NASA ThinTEAM algorithms.

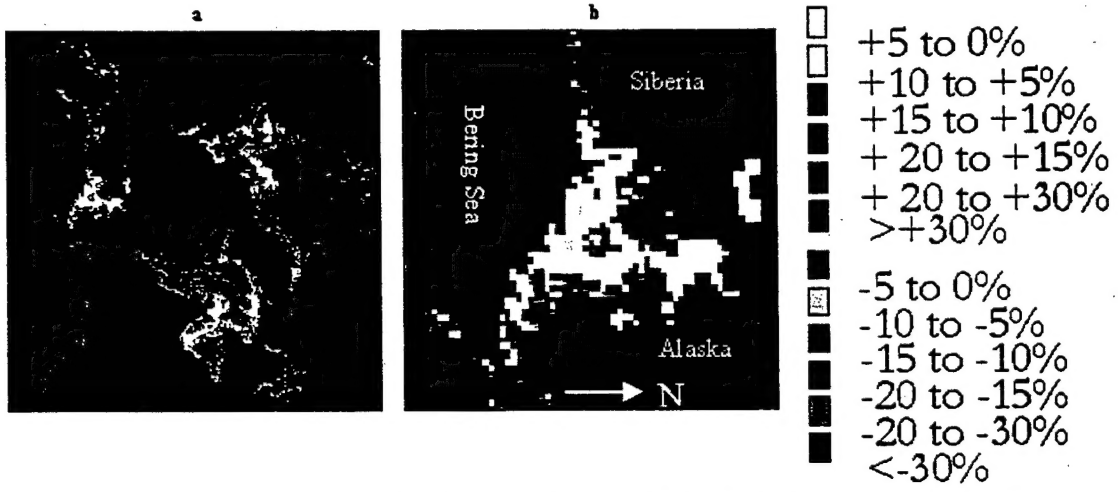

Figure 3. Difference between the Cal/Val and NASA ThinTEAM concentrations for December 12, 1999 (a) northern hemisphere and (b) Bering/Chuckchi Sea region.

2. Results of the NOGAPS/SHEBA comparisons indicate that NOGAPS has a large positive bias (warm) relative to the SHEBA data during the winter months (Figure 4). In addition, the model tends to over estimate the wind speed and produce excessive cloud cover during the winter. In contrast, the forecasts of temperature and wind were much more successful at the 850 mb level, suggesting that the source of the problem may be the sea-ice or atmospheric boundary layer scheme in NOGAPS. The impact of these errors on PIPS forecasts is currently being assessed.

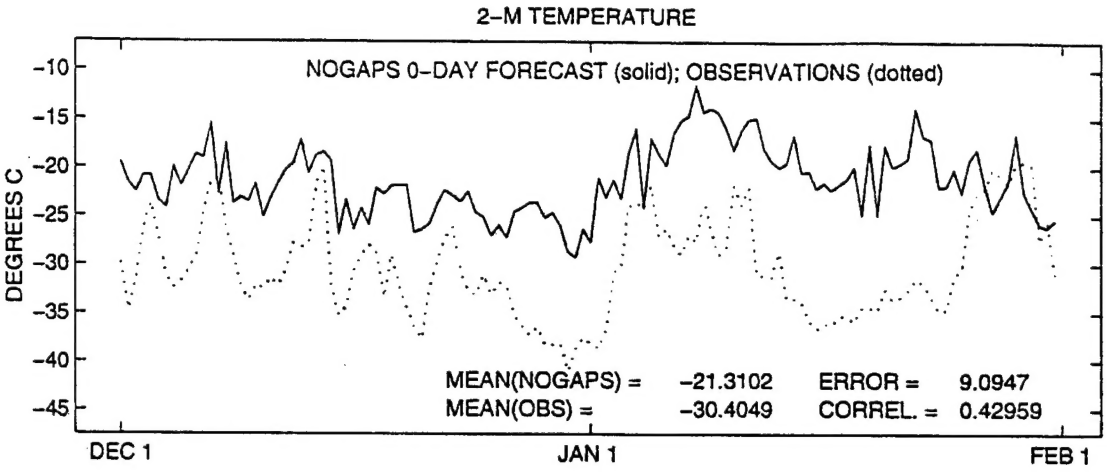

Figure 4. Temperature versus time for the period December 1, 1997 to February 1, 1998. The NOGAPS nowcast is depicted with a solid line and the SHEBA observations are shown as dotted.

PIPS IMPACT/APPLICATIONS

At the completion of this activity it is hoped to have an improved, high resolution, sea ice forecasting model that has been verified for use at high northern latitudes. Major emphasis is placed on verifying the system, so that forecasters have clear guidance on when and where they can rely strongly upon the forecast fields.

UCAR's Visiting Scientist Programs have served many federal agencies in developing valuable partnerships between the research and operational communities. The benefits have included an influx of new ideas and collaborations, and the improvement of products for the agency, the scientific community and for society at large.

PIPS TRANSITIONS

SSM/I ice motion vectors are an important source of data for constraining sea ice models (Meier et al., 2000). Code was recently transitioned to FNOC to operationally produce sea ice motion vectors.

PIPS REFERENCES

Meier, W.N., J.A. Maslanik, and C.W. Fowler, 2000. Error analysis and assimilation of remotely sensed ice motion within an Arctic sea ice model, *J. Geophys. Res.*, **105**(C2), 3339-3356.

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